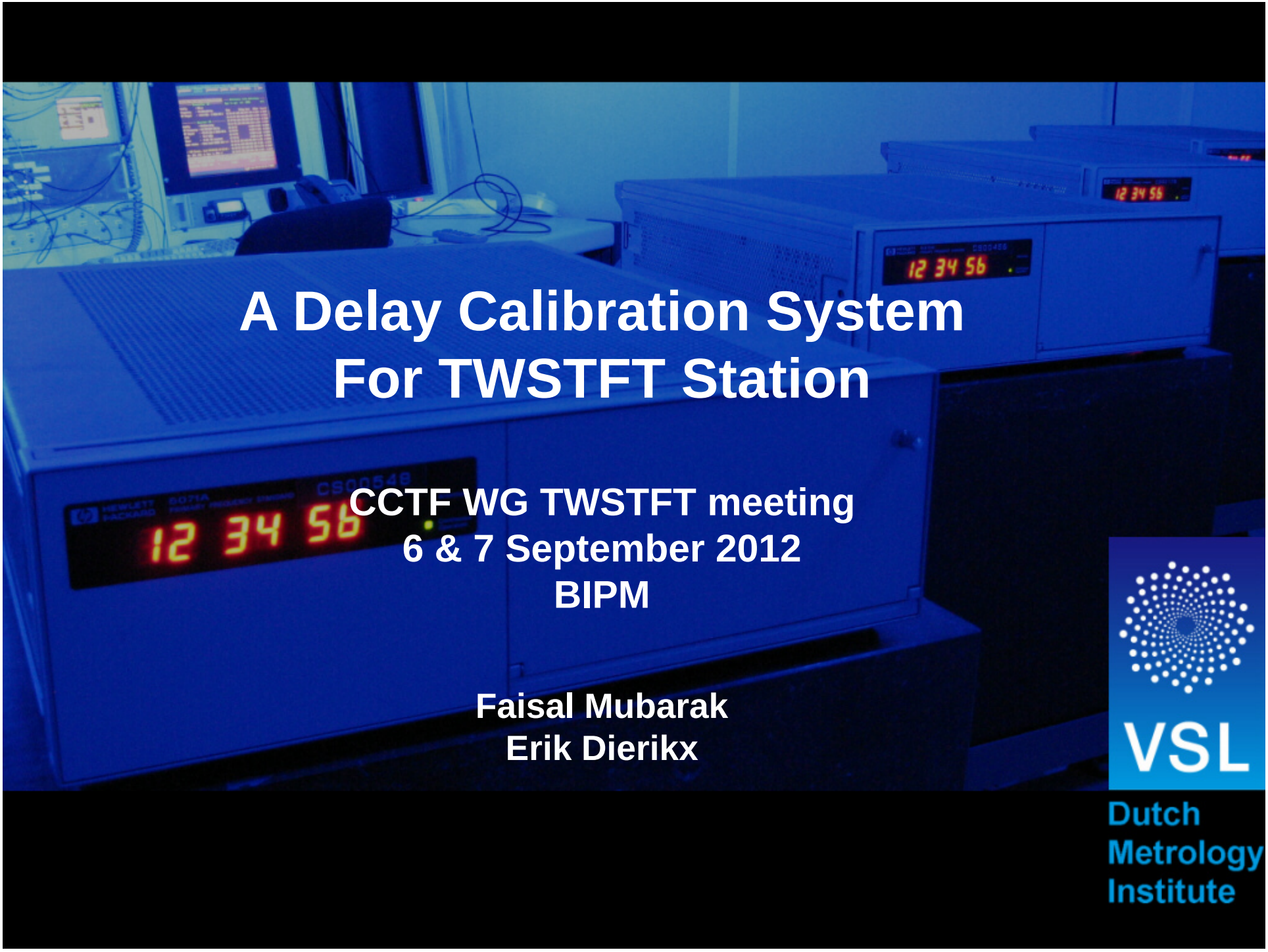

A Delay Calibration System For TWSTFT Station

CCTF WG TWSTFT meeting
6 & 7 September 2012
BIPM

Faisal Mubarak
Erik Dierikx

VSL
Dutch Metrology Institute

Outline

- TWSTFT Station at VSL
  - Tx-Rx delay measurement
- Satellite Simulator
  - TxRx Loop measurement (single mixer version)
  - Tx, Rx Loop measurements (switchable mixer)
    - ABC concept
    - Switchable oscillator
    - Switchable loops
  - Satsim delay measurements
  - Measurements Results
    - Satsim + Tx (2x)
    - Satsim + Rx (2x)
    - Satsim Loops (2)
    - ABC Loops (3x)
    - Tx Rx loop (1x)
  - Conclusions

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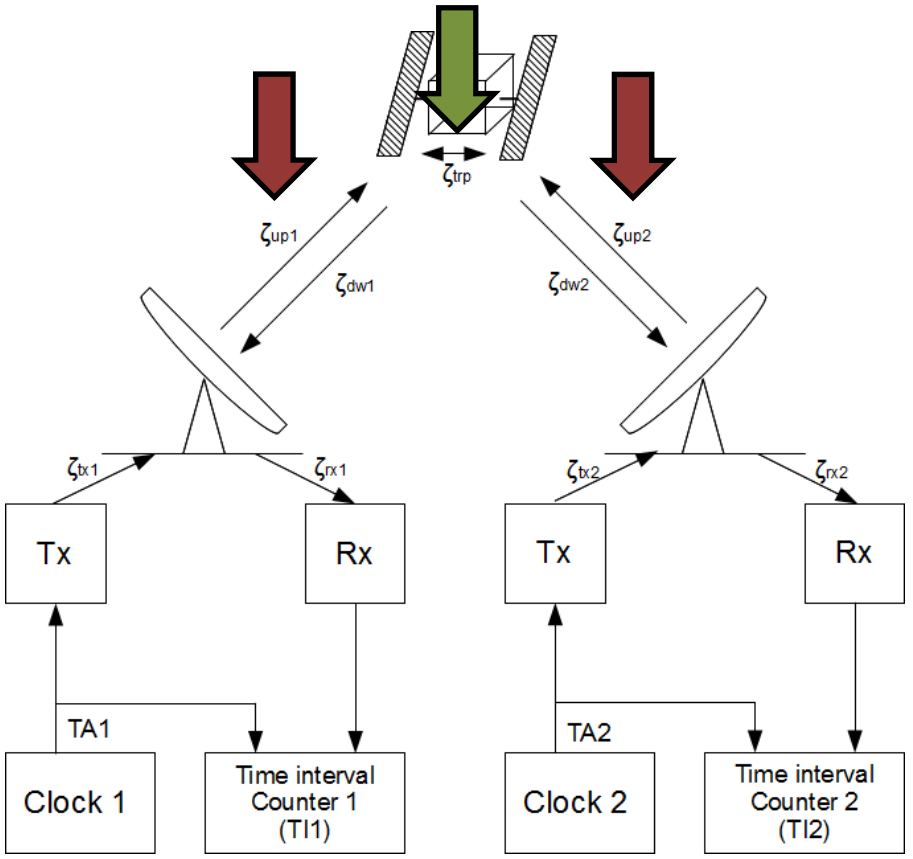
Motivation

- Transponder delay
  - Assuming transponder delay component is equivalent for both laboratories.
- Tx & Rx propagation path delays
  - Assuming antenna to antenna delay component is equivalent for both laboratories.
  - Does atmosphere/troposhpere behave frequency independent?
- Ground Station delays
  - How do we calibrate ground station Tx and Rx delay components?



$$TI_1 = (TA_2 - TA_1) + (\zeta_{tx2} + \zeta_{rx1}) + (\zeta_{up1} + \zeta_{dw1}) + \zeta_{trp1}$$

$$TI_2 = (TA_1 - TA_2) + (\zeta_{tx1} + \zeta_{rx2}) + (\zeta_{up2} + \zeta_{dw2}) + \zeta_{trp2}$$

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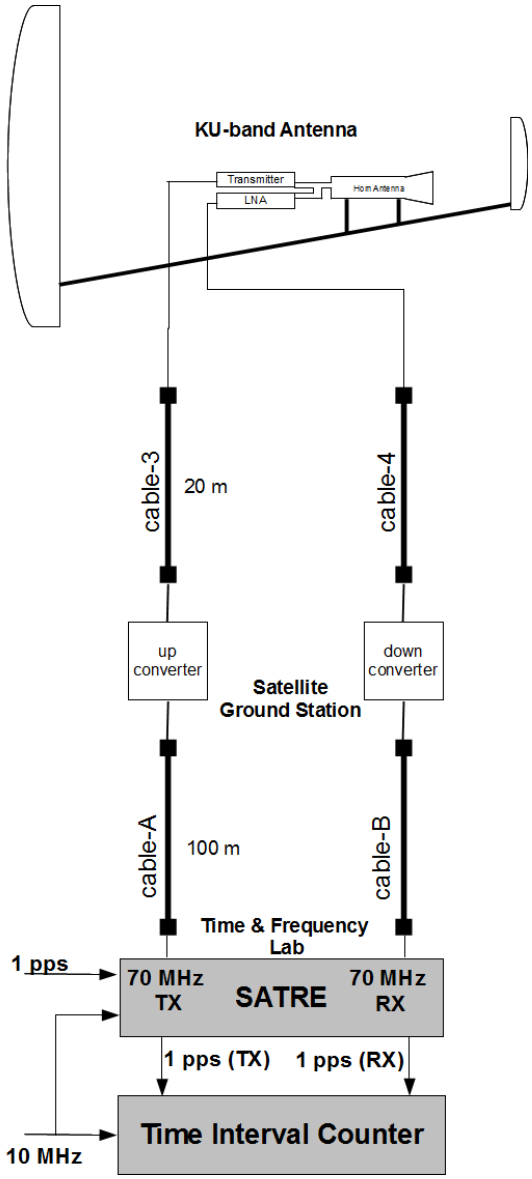
TWSTFT Station at VSL

- Time & Frequency Laboratory
  - Four cesium atomic clocks (1 pps & 10 MHz reference)
  - SATRE Modem (modulation/demodulation)
- TWSTFT Ground Station
  - 70 MHz IF to KU-Band Up/Down Convertors
  - TWSTFT delay measurement system
- KU-Band Antenna System
  - Low Noise Amplifier
  - Power Amplifier
  - KU Band Antenna



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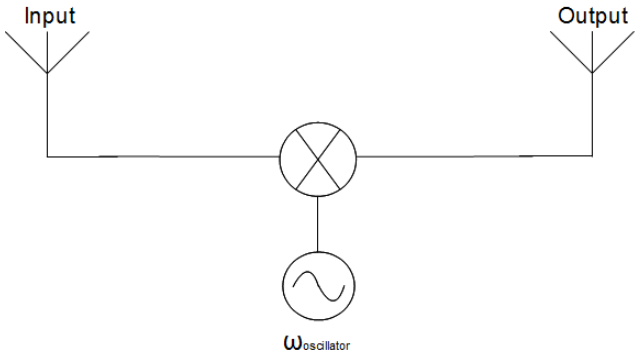
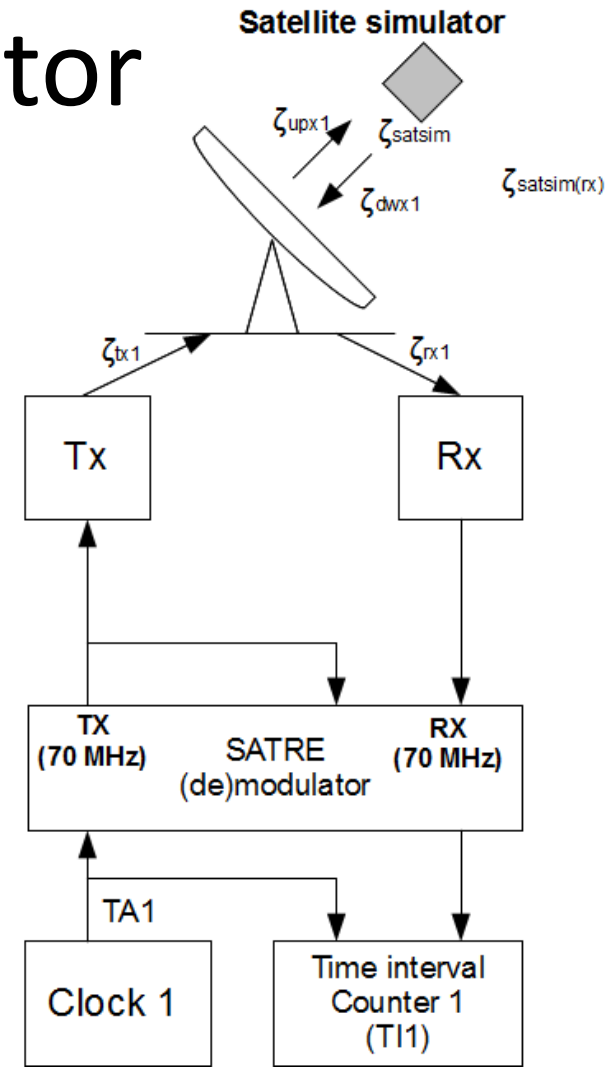
Satellite Simulator

- Single mixer approach





How do we calibrate Tx & Rx delays independently?

$$\mathbf{TI_1} = (\mathbf{TA_1} - \mathbf{TA_1}) + (\zeta_{\mathbf{tx1}} + \zeta_{\mathbf{rx1}}) + \left(\zeta_{\mathbf{upx1}} + \zeta_{\mathbf{dwx1}}\right) + \zeta_{\mathbf{satsim}}$$

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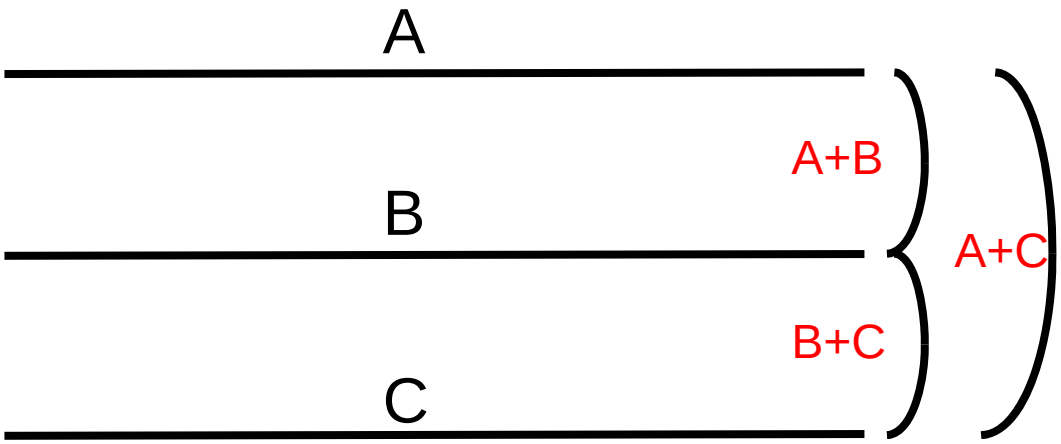
TWSTFT Delay Calibration System at VSL

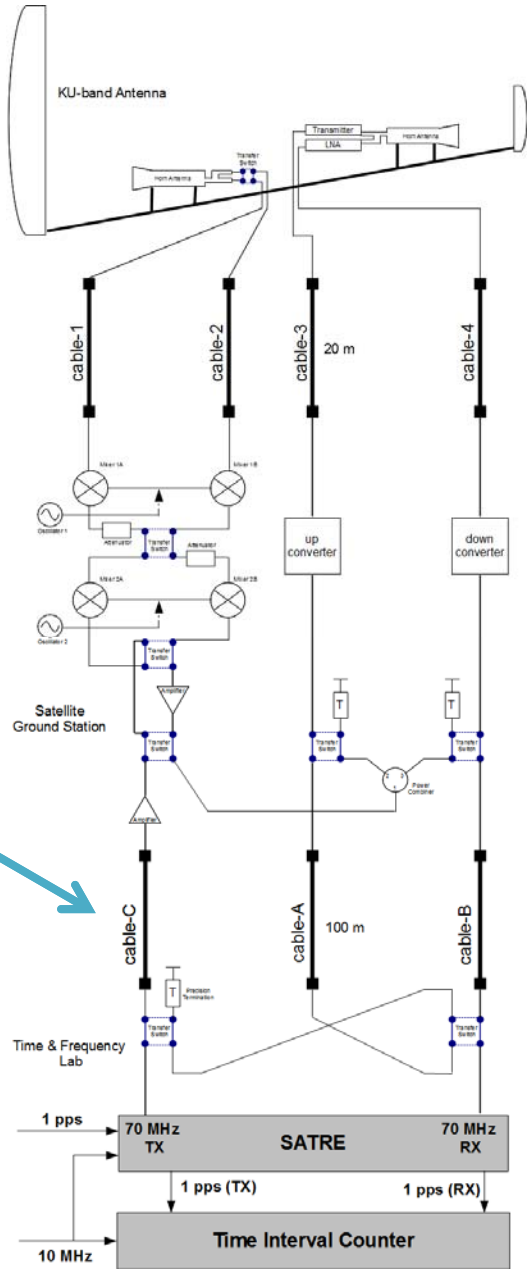
Systematic uncertainties due to switches en short interconnect cables still remain!



$$\mathrm{Delay}_{\mathrm{cable(A)}} = \frac{M_{AB} + M_{AC} - M_{BC}}{2}$$

$$\mathrm{Delay}_{\mathrm{cable(B)}} = \frac{M_{AB} + M_{BC} - M_{AC}}{2}$$

$$\mathrm{Delay}_{\mathrm{cable(C)}} = \frac{M_{AC} + M_{BC} - M_{AB}}{2}$$



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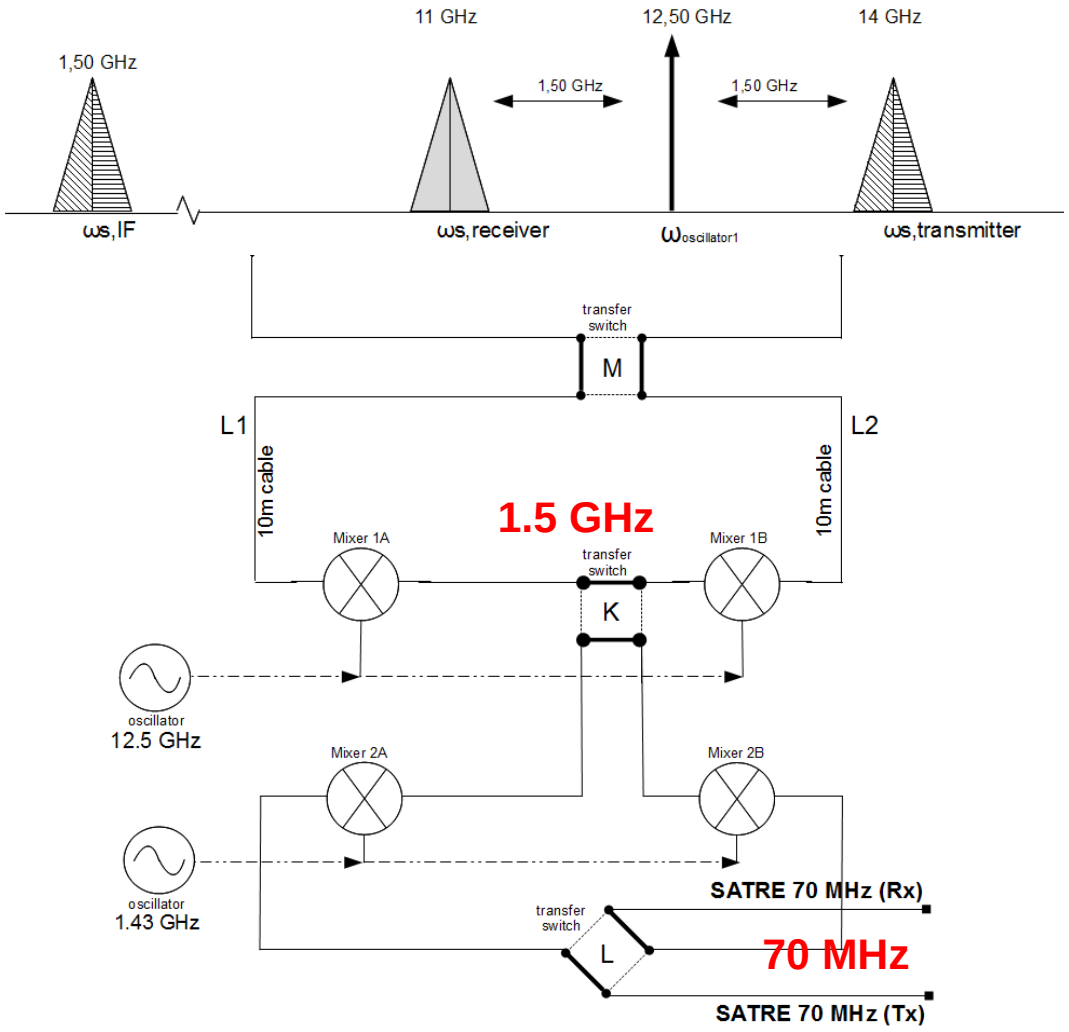

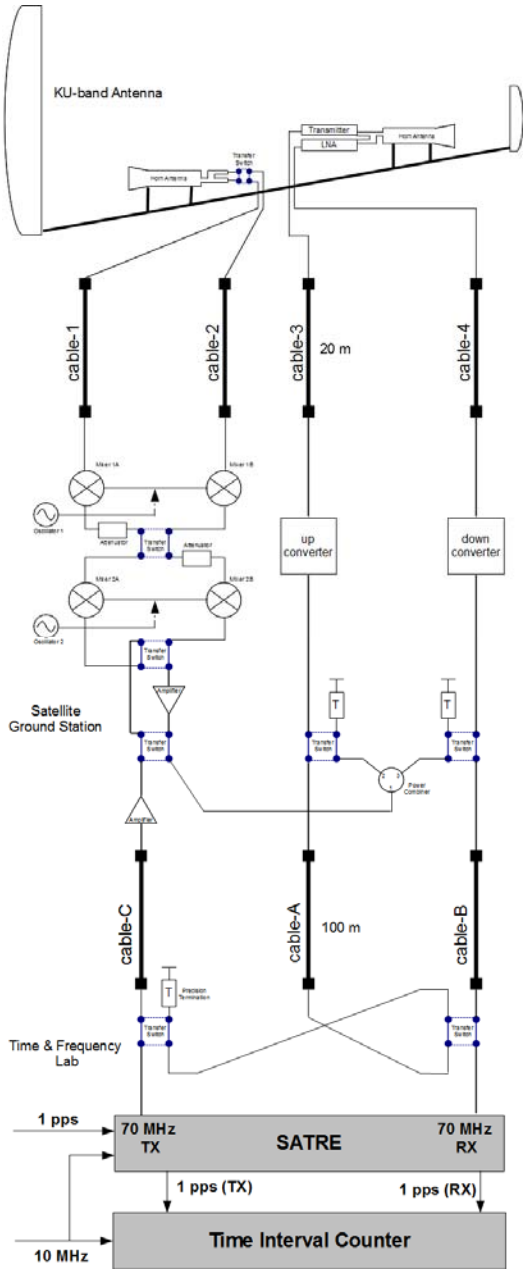

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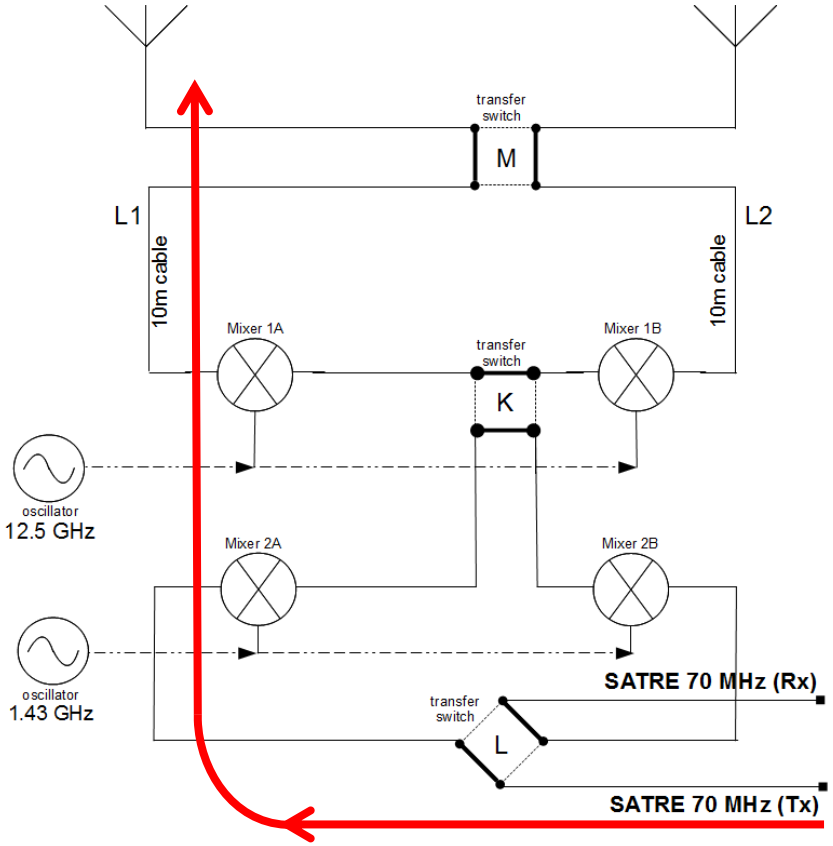
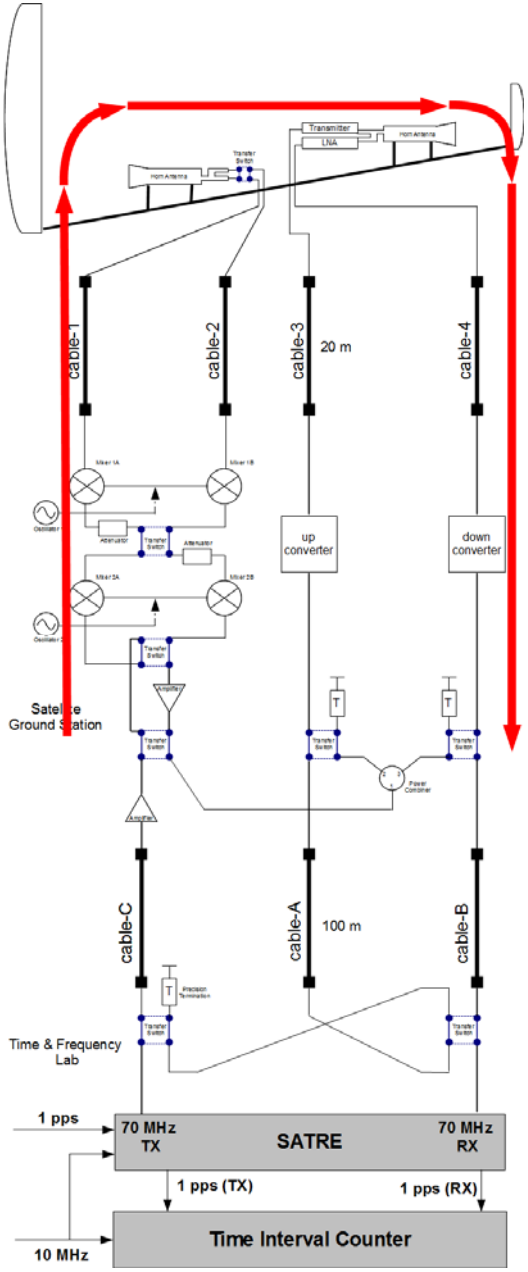
[1] F.Mubarak, E.Dierikx, "Dual-Stage Quad-Mixer Satellite Simulator for TWSTFT Station", EFTF 2011

Tx via SatSim path1; Rx via D/C

Measurement 1: Transmitting from satsim path 1





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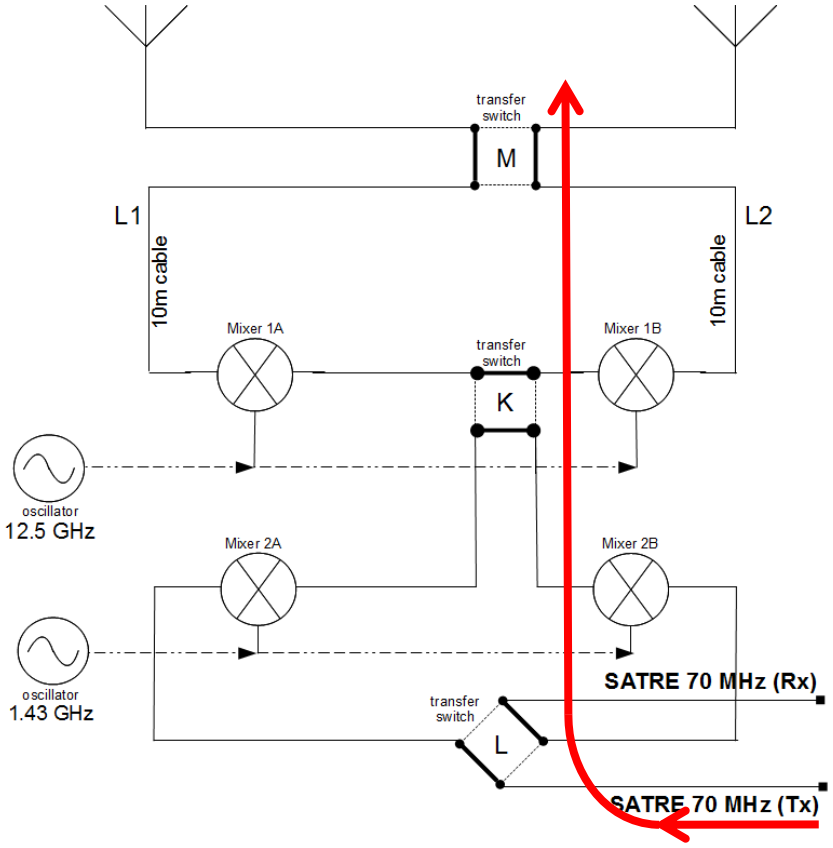
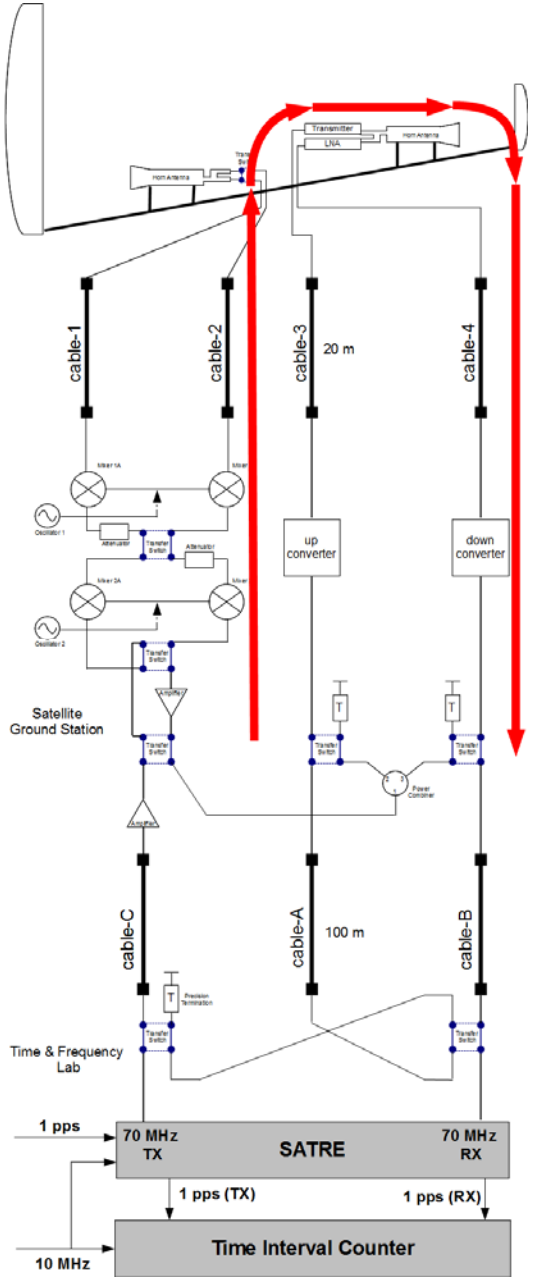
Tx via SatSim path2; Rx via D/C

Measurement 2: Transmitting from satsim path 2





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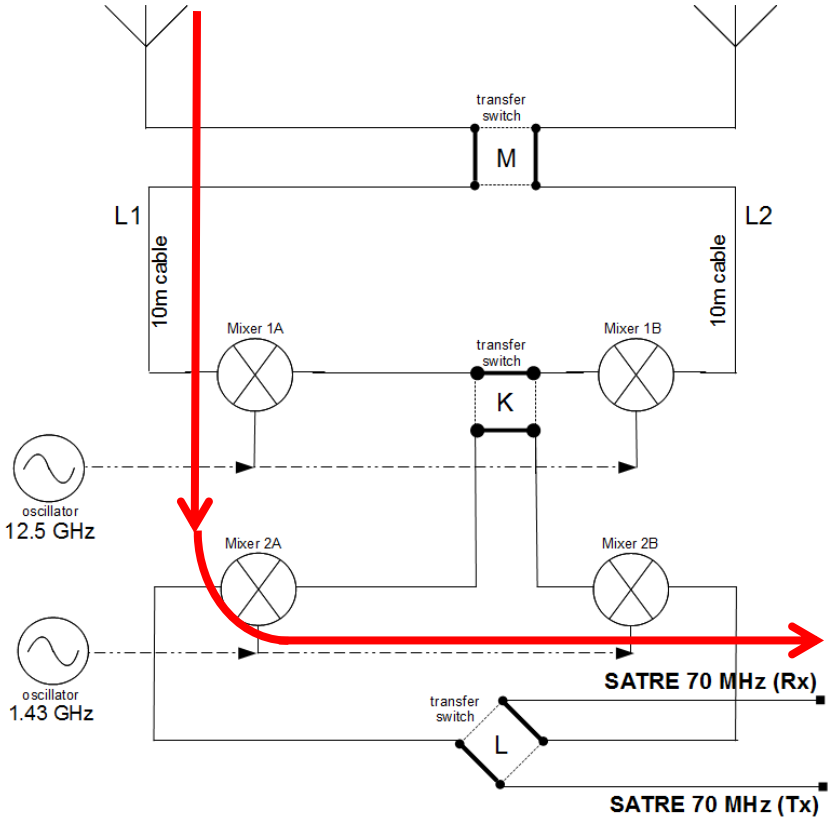
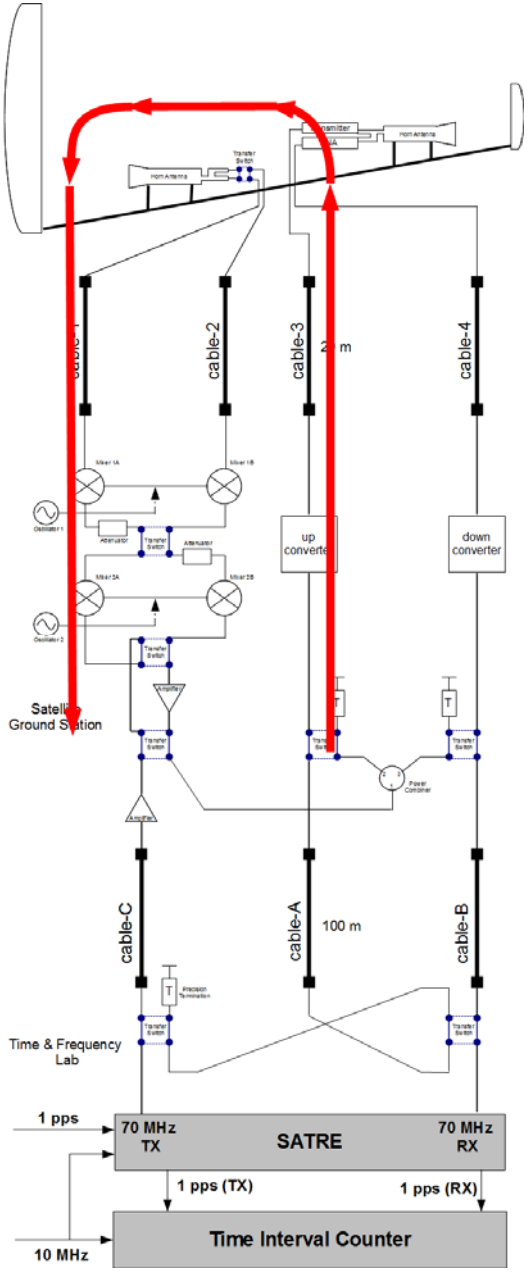
Tx via U/C; Rx via SatSim path 1

Measurement 3: Receiving with satsim path 1





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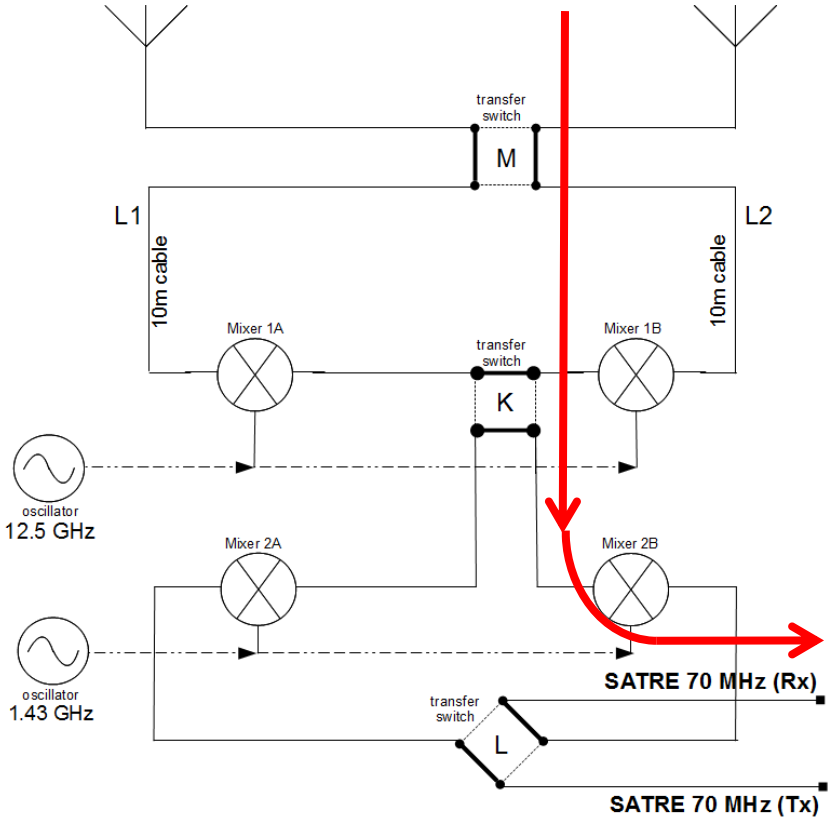
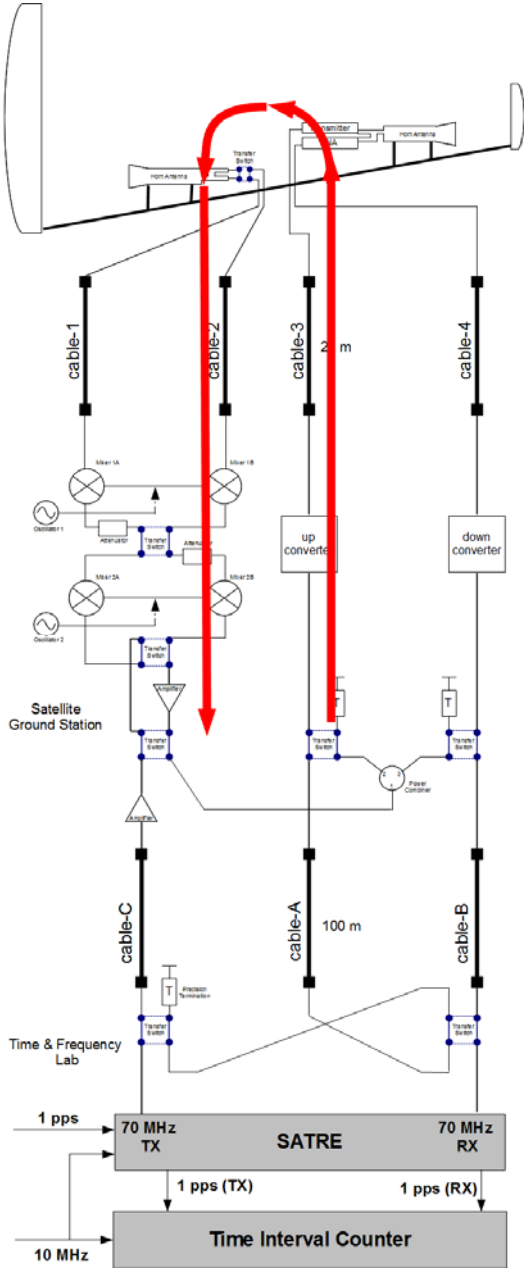
Tx via U/C; Rx via SatSim path 2

Measurement 4: Receiving with satsim path 2





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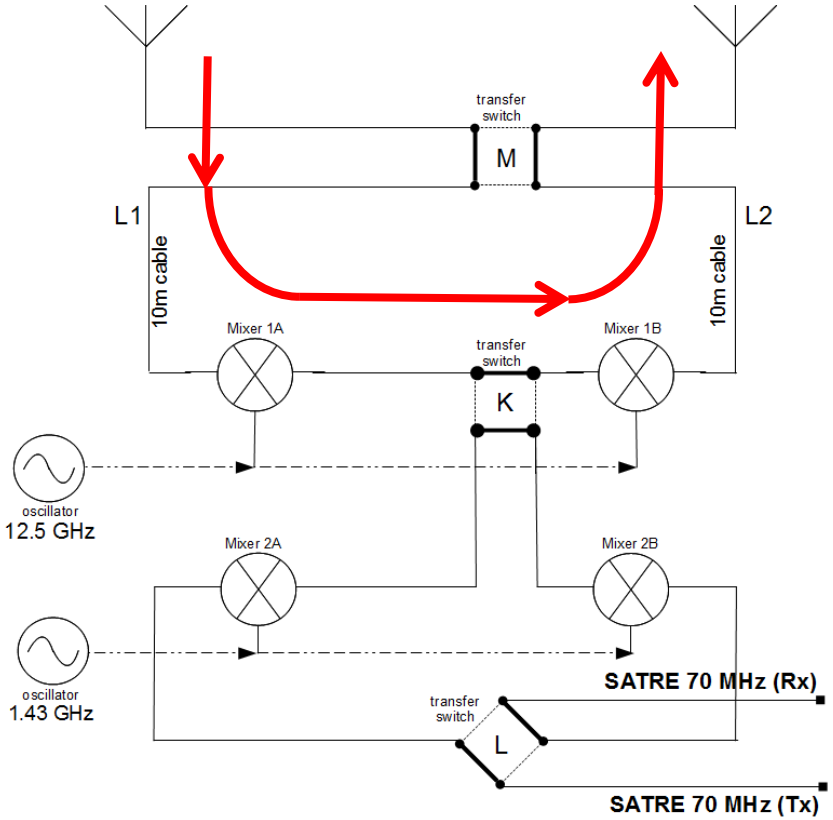
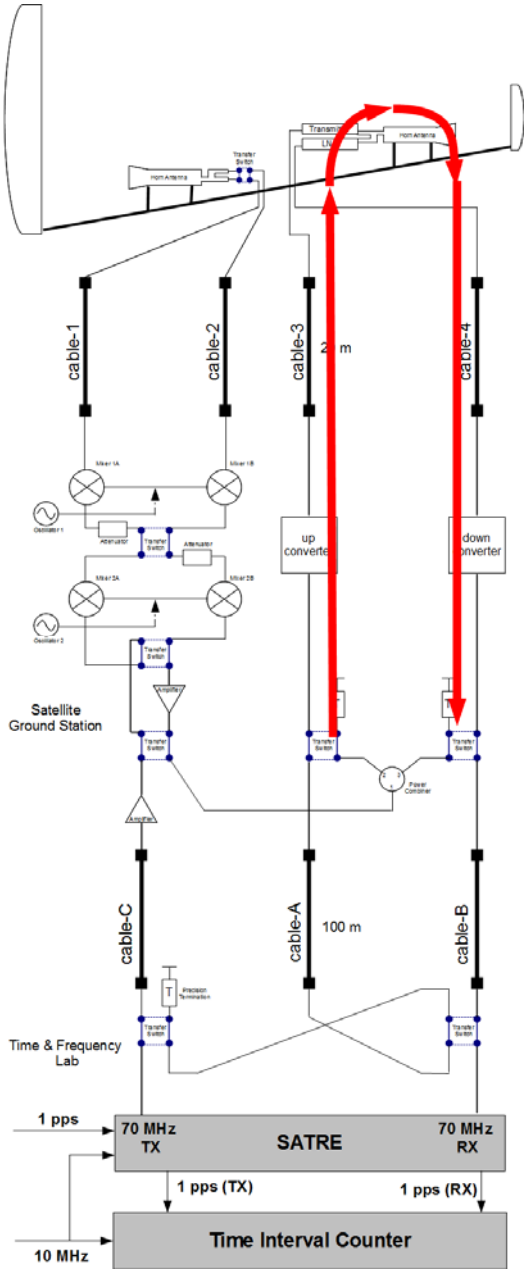
SatSim mode
Tx via U/C; Rx via D/C

Measurement 5: Tx + Rx + Satsim(loop1)





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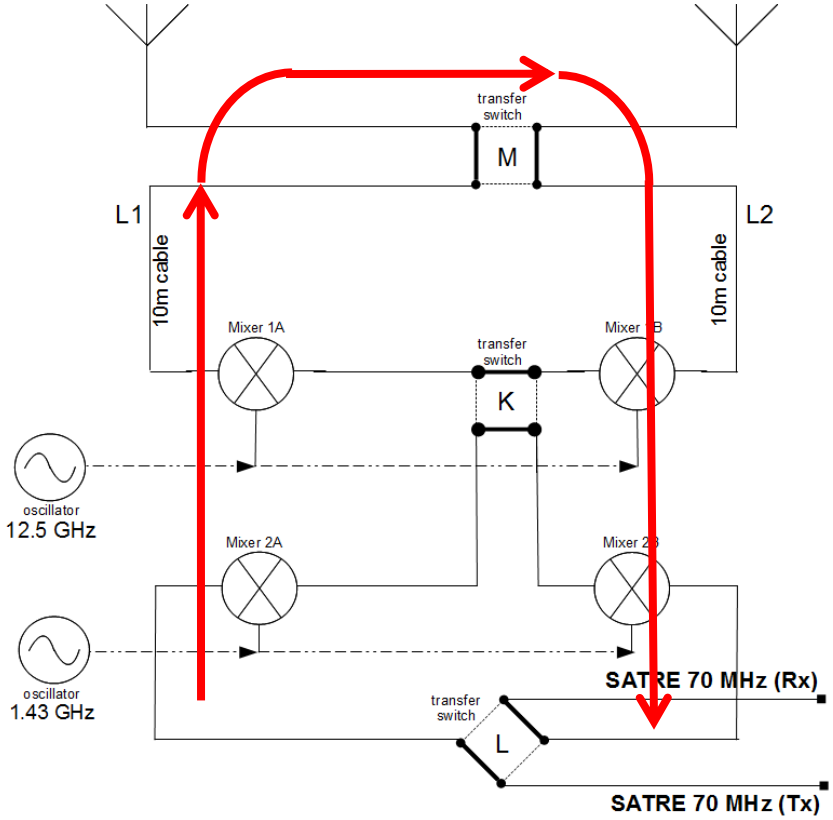
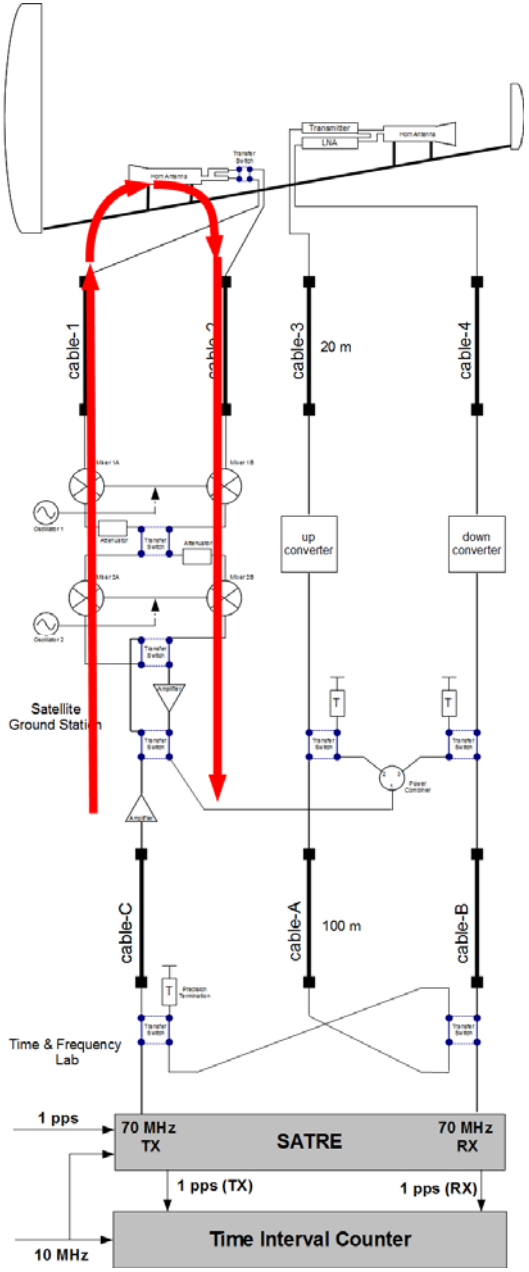
Measurement 6: Satsim(loop-A)





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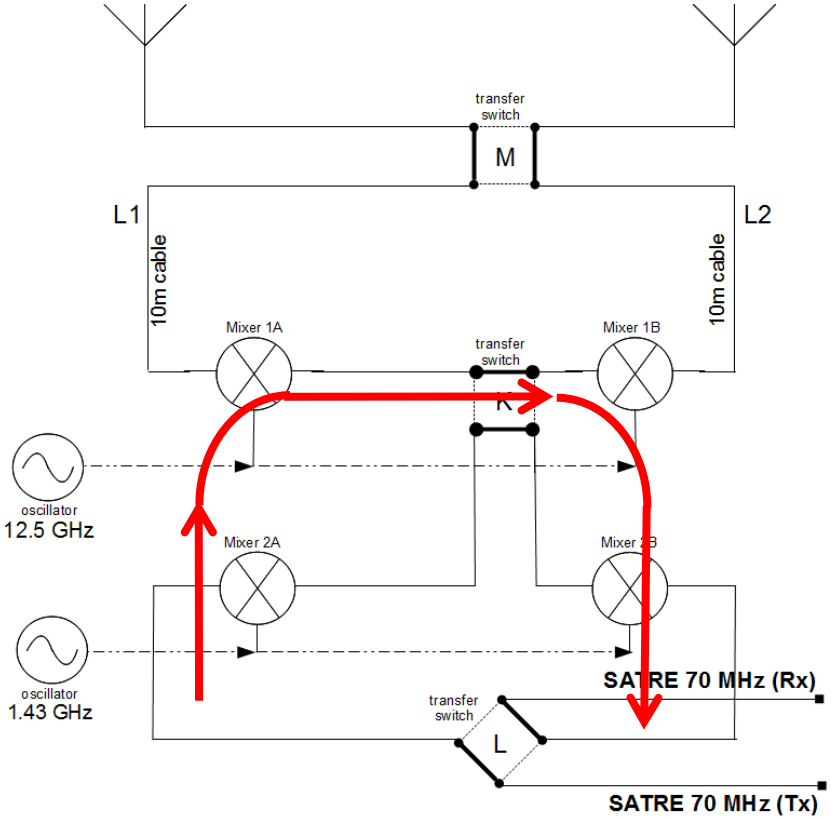
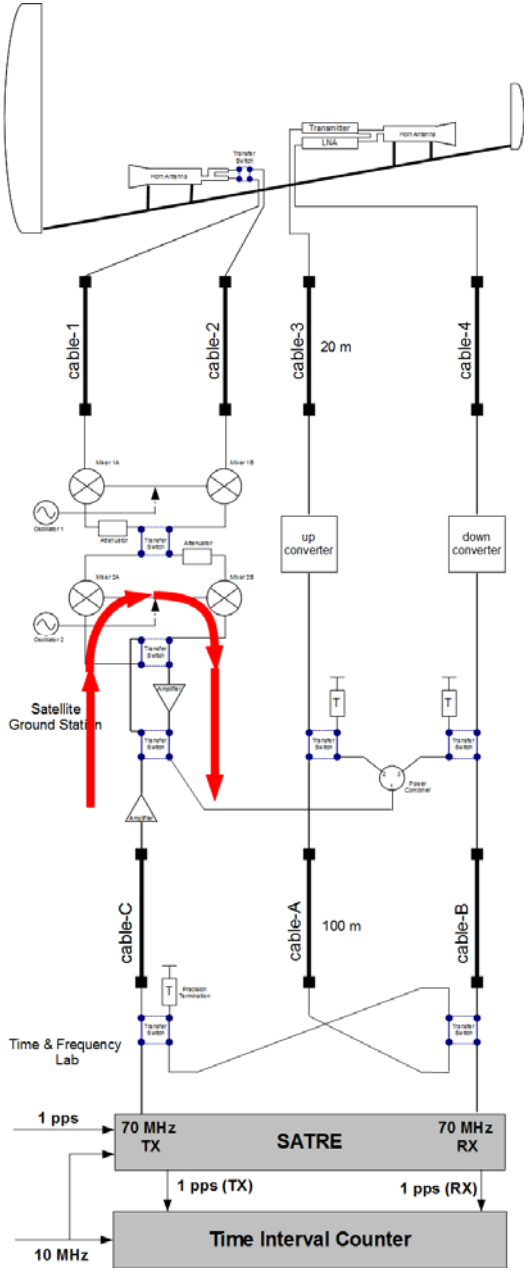
Measurement 7: Satsim(loop-B)





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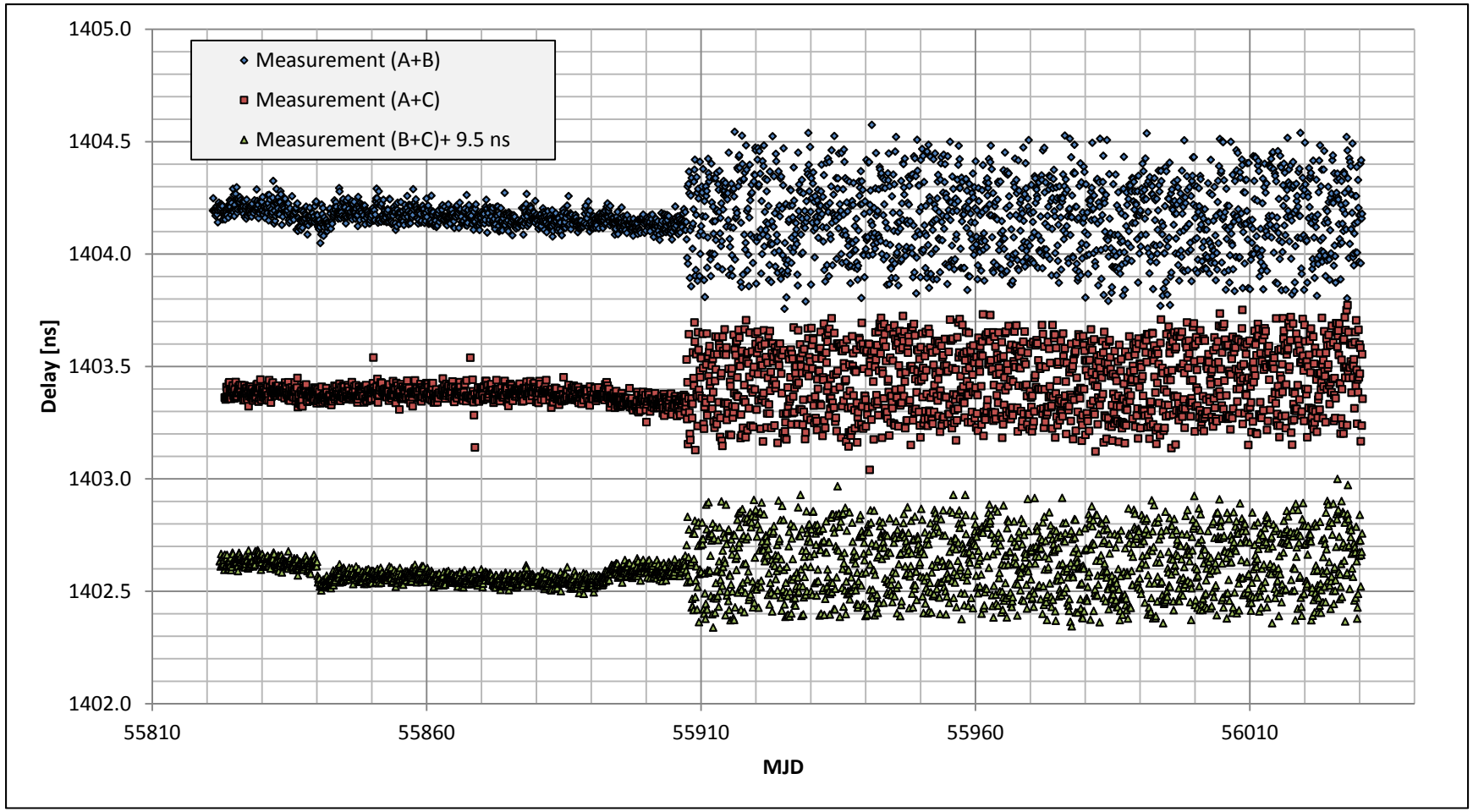
Measurement ABC



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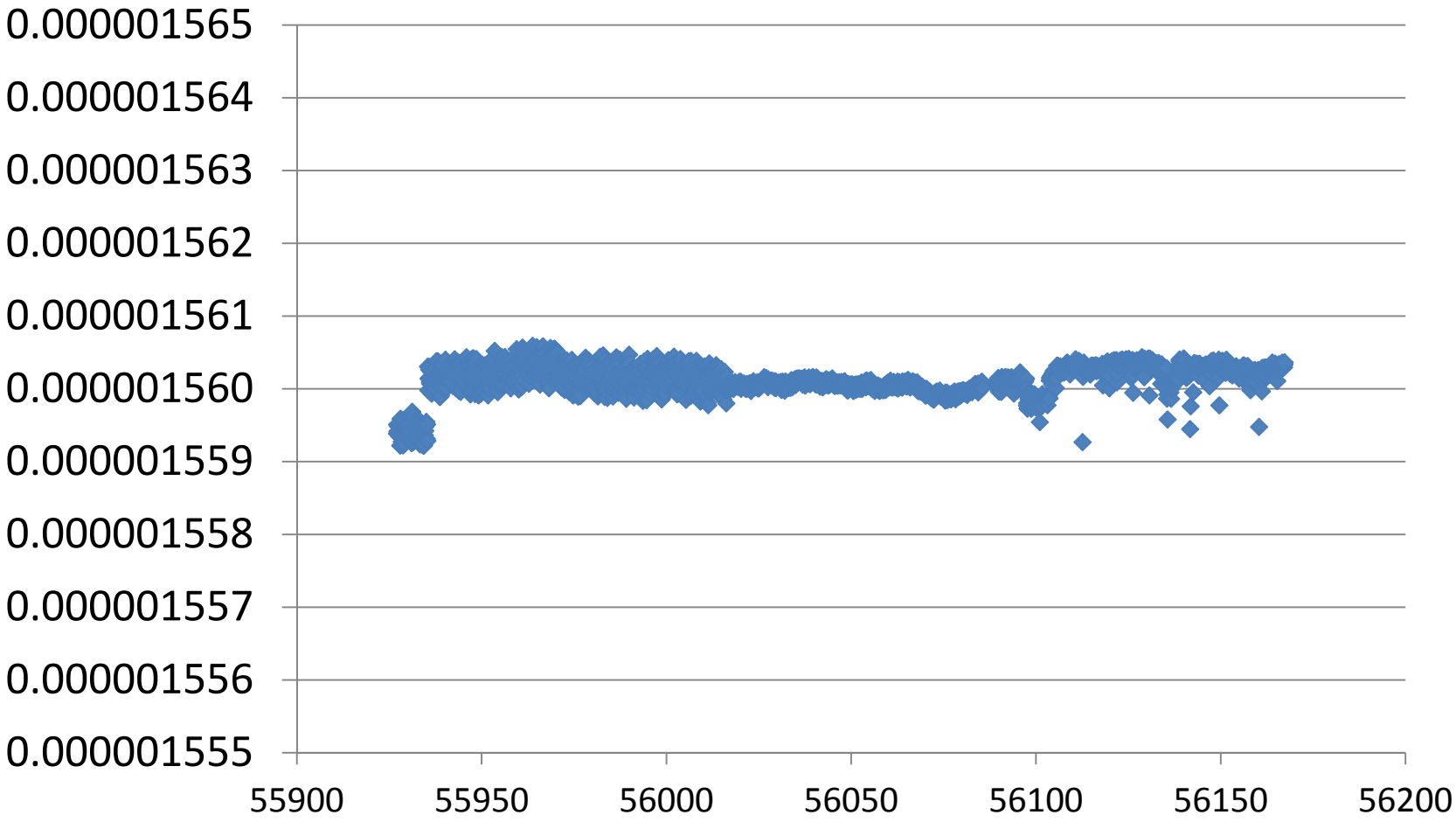
Tx via U/C; Rx via SatSim



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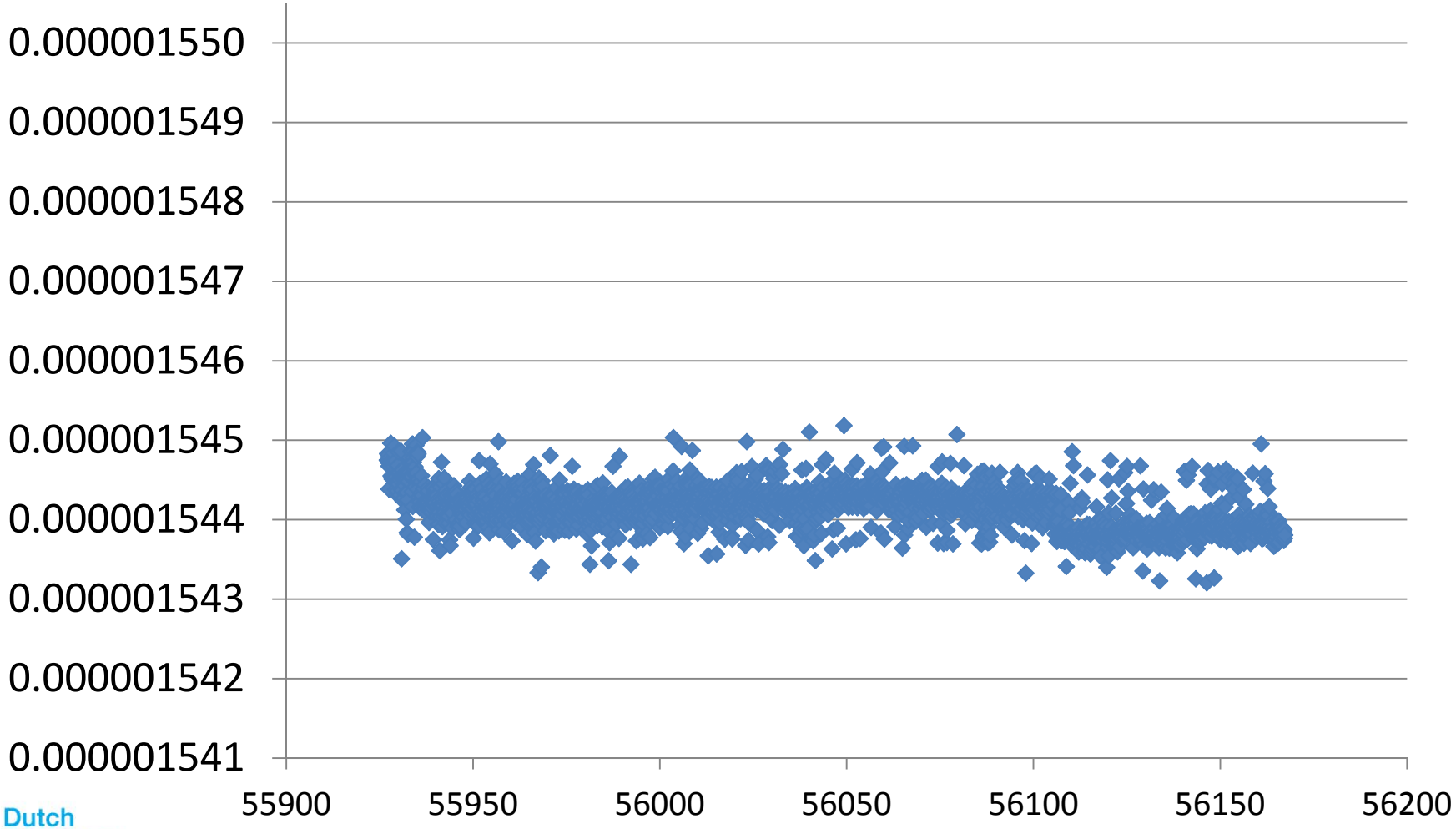
Tx via SatSim; Rx via D/C



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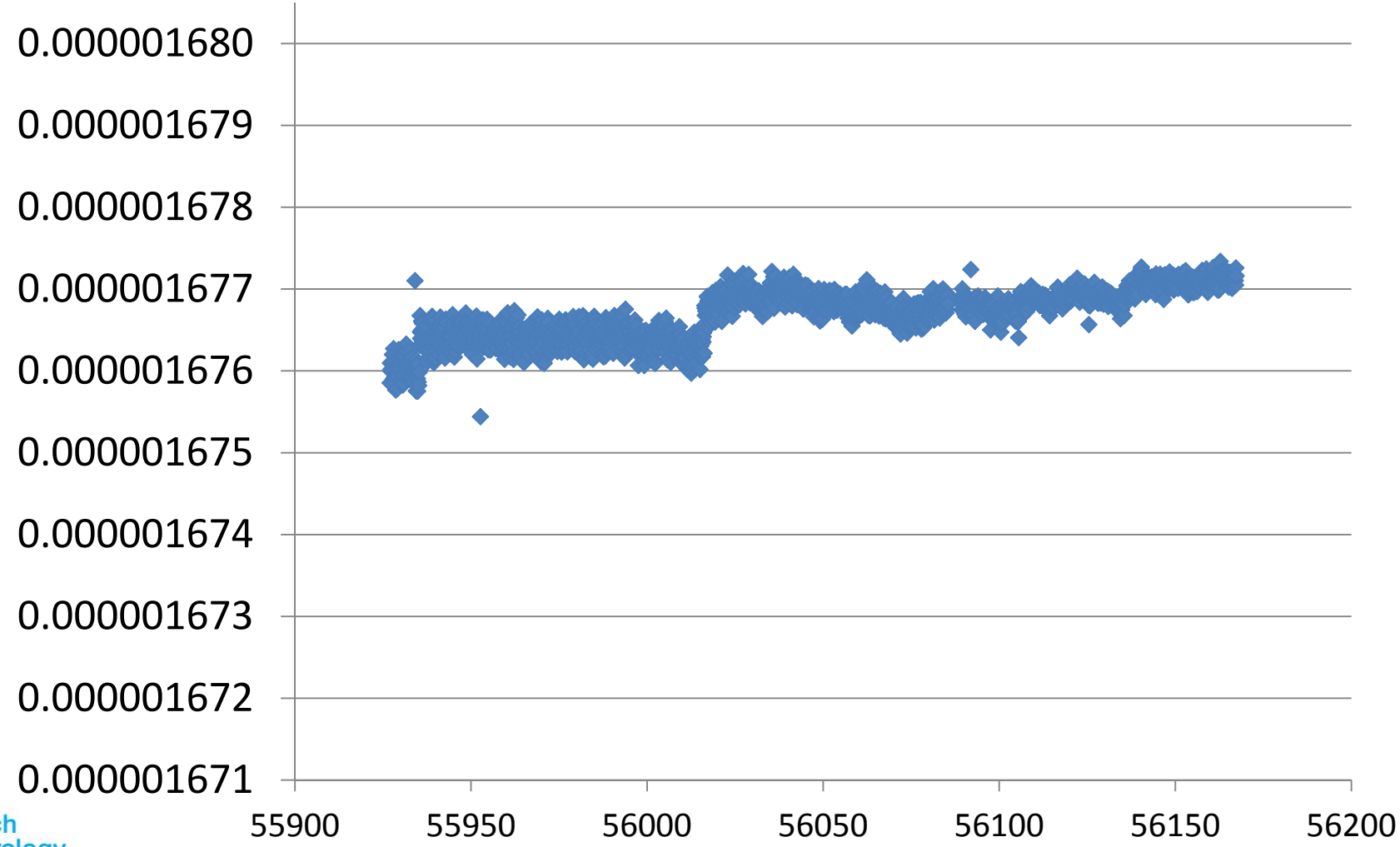
SatSim mode
Tx via U/C; Rx via D/C



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Conclusions

- Successful tests of the new automated TWSTFT station delay calibration system in the laboratory environment.
- The stability of the measurements is good.
- Systematic offsets
- Need to test effect from reflections due to impedance miss-matches.
- Need to check frequency and power level dependence.

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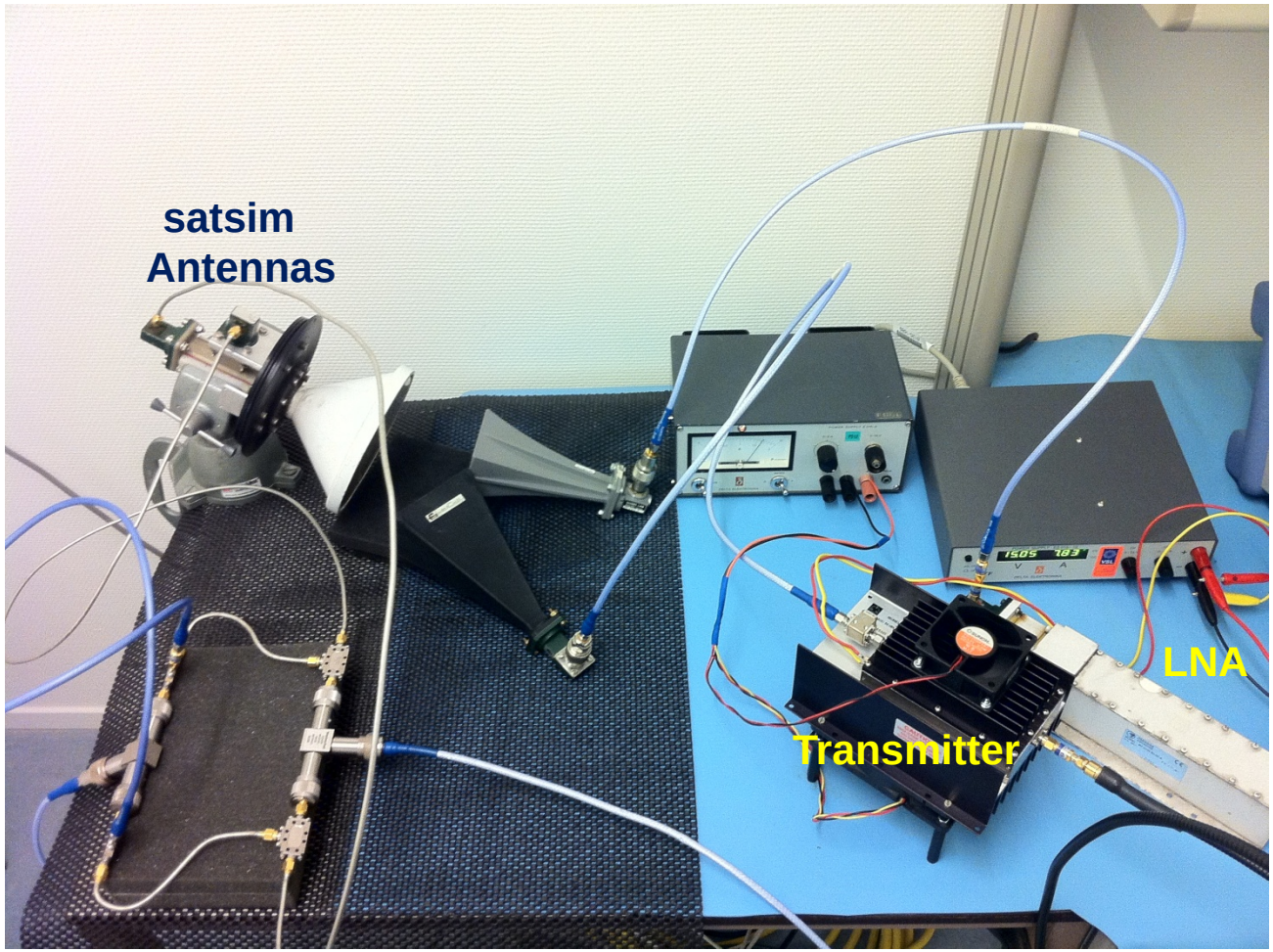
A TWSTFT link in the lab

Test bench for TWSTFT ground station



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Dual-Stage Quad Mixer satsim